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Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

00311670.4

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

I.L.C. HATTEN-HECKMAN

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CLEANING OF OPTICAL ELEMENTS IN LITHOGRAPHIC PROJECTION APPARATUS

The present invention relates to a method of cleaning optical elements in a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table for holding a mask;

a second object table for holding a substrate; and

a projection system for imaging an irradiated portion of said mask onto a target portion of said substrate.

For the sake of simplicity, the projection system may hereinafter be referred to as the "lens"; however, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, and catadioptric systems, for example. The illumination system may also include elements operating according to any of these principles for directing, shaping or controlling the projection beam, and such elements may also be referred to below, collectively or singularly, as a "lens". In addition, the first and second object tables may be referred to as the "mask table" and the "substrate table", respectively.

Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the mask (reticle) may contain a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto the target portion (comprising one or more dies) of a substrate (silicon wafer) which has been coated with a layer of radiation-sensitive material (resist). In general, a single wafer will contain a whole network of adjacent target portions which are successively irradiated via the mask, one at a time. In one type of lithographic projection apparatus, each target portion is irradiated by exposing the entire mask pattern onto the target portion in one go; such an apparatus is commonly referred to as a wafer stepper. In an alternative apparatus -

which is commonly referred to as a step-and-scan apparatus - each target portion is irradiated by progressively scanning the mask pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or anti-parallel to this direction; since, in general, the projection system will have a magnification factor M (generally < 1), the speed V at which the substrate table is scanned will be a factor M times that at which the mask table is scanned. More information with regard to lithographic devices as here described can be gleaned from International Patent Application WO97/33205, for example.

In general, lithographic apparatus contain a single mask table and a single substrate table. However, machines are becoming available in which there are at least two independently movable substrate tables; see, for example, the multi-stage apparatus described in International Patent Applications WO98/28665 and WO98/40791. The basic operating principle behind such multi-stage apparatus is that, while a first substrate table is at the exposure position underneath the projection system for exposure of a first substrate located on that table, a second substrate table can run to a loading position, discharge a previously exposed substrate, pick up a new substrate, perform some initial measurements on the new substrate and then stand ready to transfer the new substrate to the exposure position underneath the projection system as soon as exposure of the first substrate is completed; the cycle then repeats. In this manner, it is possible to increase substantially the machine throughput, which in turn improves the cost of ownership of the machine. It should be understood that the same principle could be used with just one substrate table which is moved between exposure and measurement positions.

To reduce the size of features that can be imaged using a lithographic projection apparatus, it is desirable to reduce the wavelength of the illumination radiation. Ultraviolet wavelengths of less than 180nm are therefore currently contemplated, for example 157nm or 126nm. Also contemplated are extreme ultraviolet (EUV) wavelengths of less than 50nm, for example 13.5nm. Suitable sources of UV radiation include Hg lamps and excimer lasers. EUV sources contemplated include laser-produced plasma sources,

discharge sources and undulators or wigglers provided around the path of an electron beam in a storage ring or synchrotron.

In the case of EUV radiation, the projection system will generally consist of an array of mirrors, and the mask will be reflective; see, for example, the apparatus discussed in WO 99/57596 (P-0111).

However, apparatus which operate at such wavelengths are significantly more sensitive to the presence of contaminant particles than those operating at higher wavelengths. Contaminant particles such as hydrocarbon molecules and water vapor may be introduced into the system from external sources, or they may be generated within the lithographic apparatus itself. For example the contaminant particles may include the debris and by-products that are sputtered loose from the substrate, for example by an EUV radiation beam, or molecules produced through evaporation of plastics, adhesives and lubricants used in the apparatus.

These contaminants tend to adsorb to the optical components in the system and cause a loss in transmission of the radiation beam. When using 157nm radiation, a loss in transmission of about 1% is observed when only one or a few monolayers of contaminant particles form on each optical surface. Such a loss in transmission is unacceptably high. Further, the uniformity requirement on the projection beam intensity for such systems is less than 0.2%. Localised contamination can cause this requirement not to be met.

There is also a risk that the adsorption of contaminant particles on the surface of the optical components, or within the optical surface in the case of a porous surface, e.g. an anti-reflection coating, may cause damage, for example cracking, to the optical components themselves. Such damage can occur if the optical components are suddenly irradiated with UV radiation, for example 157nm radiation, at full power. The irradiation will cause rapid evaporation of the smaller contaminant particles, such as water molecules, which are trapped within said porous surface of the optical component, hence damaging the optical surface itself. Such damage is extremely costly and even a minimal risk of this occurring should be avoided. It is therefore desired that the optical components in a lithographic apparatus are kept as free of contaminants as possible.

Previous methods for cleaning optical components include, for example, the use of ozone as a cleaning material, its activity being increased by the presence of UV radiation. However, methods involving UV radiation are very harsh and may damage the optical surfaces. In particular, the mask, which generally comprises a teflon-based or other organic material, can be damaged by the use of such methods.

A further problem associated with apparatus for use with EUV radiation relates specifically to the presence of water molecules in the apparatus. Typically, the high vacuum systems required for operation in EUV lithography tools contain a high partial pressure of water. However, the presence of water in combination with EUV radiation has a tendency to cause oxidation of mirrors. This is an irreversible and highly damaging process and leads to a very significant loss in mirror reflection. Due to the restrictively high cost of replacing the mirrors, this ultimately leads to the operation of the system with poor reflection levels and therefore a reduction in productivity. The reduction in lifetime of the mirrors which also results is a further distinct economic disadvantage.

Oxidation protection cap layers have been suggested as a potential solution to this problem. However, very few successful results in this area have so far been demonstrated. No protective method has yet been found which can increase the lifetime of mirrors used in EUV systems to greater than 15 hours. This is considerably lower than the 10,000 hours that are desired.

It is therefore an object of the invention to provide an improved method of cleaning the optical components, in particular the mask, in a lithographic projection apparatus. It is also an object of the invention to provide a method of reducing the oxidative damage caused to mirrors in EUV systems.

According to the invention there is provided a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table for holding a mask;

a second object table for holding a substrate; and

a projection system for imaging an irradiated portion of said mask onto a target portion of said substrate; characterized by:

a source for supplying microwave and/or infra-red radiation.

The inventors have found that supplying microwave and/or infra-red radiation to a lithographic projection apparatus may have the effect of both cleaning the optical components in the system and reducing the oxidative damage to mirrors. Cleaning is carried out by directing a source of suitable radiation at an optical component in the system. The radiation may be absorbed by the contaminant molecules adsorbed to the surface of the optical component. Molecules which absorb radiation become excited and, should they gain sufficient energy, will evaporate from the surface of the optical component. Microwave and/or infra-red radiation can therefore be used in this manner to remove adsorbed contaminants from optical components.

The invention provides a mild, yet effective manner of cleaning optical components in lithographic projection apparatus. After cleaning, the transmission of the radiation beam is increased and the uniformity is also improved. Further, cleaning the optical components significantly reduces the number of small molecules such as water which are adsorbed to the optical surface. This in turn reduces the likelihood of cracks forming in, or other damage occurring to, the optical components due to the uncontrolled evaporation of such molecules when irradiated with the UV projection beam.

The use of the present invention also avoids damage to the delicate optical surfaces which may be present in the apparatus. In particular, the intensity of the microwave and/or infra-red radiation can be varied, allowing initial radiation to be carried out at a low intensity. This method is therefore suitable for use with, for example, teflon-comprising masks.

Further, cleaning with infra-red radiation, rather than UV radiation has the advantage that the reticle and lens elements generally employed with 157nm light do not absorb radiation in this frequency range. The lens elements generally comprise CaF_2 or MgF_2 and the reticle generally comprises quartz which is free of hydroxyl groups. None of these materials absorbs infra-red radiation.

This has the advantage that both sides of each optical element may be cleaned simultaneously using a single infra-red source. Further, the method is efficient since the radiation is specifically absorbed by the contaminants rather than the optical element itself. The cleaned optical elements are not themselves heated by the cleaning process and can therefore be used immediately for an exposure.

The lithographic apparatus of the invention may also reduce the oxidative damage to mirrors which tends to occur in EUV systems. In this embodiment of the invention, the apparatus is irradiated with infra-red or microwave radiation having a frequency which corresponds to a rotational or vibrational frequency of water. By illuminating at such a frequency, the water molecules in the apparatus are selectively heated. This causes evaporation and removal of the water molecules which may be adsorbed to the various surfaces in the apparatus, thereby reducing oxidation of mirrors.

Since this method selectively targets water molecules, this provides an efficient manner in which water can be removed from the system, whilst avoiding heating the apparatus itself. This increases the life-time of EUV mirrors which is essential for the economic viability of EUV equipment, without sacrificing the demands on thermal stability of the tool, a feature which is required for low down-time.

The invention also provides a method of manufacturing a device using a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table for holding a mask;

a second object table for holding a substrate; and

a projection system for imaging irradiated portions of said mask onto target portions of said substrate; the method comprising the steps of:

providing a mask bearing a pattern to said first object table;

providing a substrate provided with a radiation-sensitive layer to said second object table;

irradiating portions of the mask with said projection beam; and

imaging said irradiated portions of the mask onto said target portions of said substrate; characterized by the step of:

removing contaminant particles from the apparatus by irradiating with microwave and/or infra-red radiation.

The invention further provides a method of manufacturing a device using a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table for holding a mask;

a second object table for holding a substrate; and

a projection system for imaging irradiated portions of said mask onto target portions of said substrate; the method comprising the steps of:

providing a mask bearing a pattern to said first object table;

providing a substrate provided with a radiation-sensitive layer to said second object table;

irradiating portions of the mask with said projection beam; and

imaging said irradiated portions of the mask onto said target portions of said substrate; characterized by the step of:

determining the level of contamination of an optical component by irradiating said optical component with microwave and/or infra-red radiation and monitoring the degree of absorption of said radiation.

This latter method provides that the level of contamination of the optical components in the system can be determined, usually prior to exposure.. If the degree of absorption is undesirably high, indicating the presence of contaminants on the optical surfaces, cleaning can be carried out, or continued, either using the method of the invention or using other methods. This provides that exposure can be delayed until it is known that the contaminant levels are acceptable. It is therefore possible to ensure that the

transmission and uniformity levels during every exposure are high, thus maximizing the efficiency of the apparatus.

In a manufacturing process using a lithographic projection apparatus according to the invention, a pattern in a mask is imaged onto a substrate which is at least partially covered by a layer of radiation-sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemo-mechanical polishing, etc., all intended to finish off an individual layer. If several layers are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices (dies) will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4.

Although specific reference may be made in this text to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "exposure area" or "target portion", respectively.

The invention is described below with reference to a coordinate system based on orthogonal X, Y and Z directions with rotation about an axis parallel to the I direction denoted Ri. The Z direction may be referred to as "vertical" and the X and Y directions as "horizontal". However, unless the context otherwise demands, this should not be taken as requiring a specific orientation of the apparatus.

The invention and its attendant advantages will be further described below with reference to exemplary embodiments and the accompanying schematic drawings, in which:

Figure 1 depicts a lithographic projection apparatus according the invention; and

Figure 2 depicts the mask stage of a specific embodiment of the invention.

In the drawings, like parts are identified by like references.

Embodiment 1

Figure 1 schematically depicts a lithographic projection apparatus according to the invention. The apparatus comprises:

a radiation system LA, IL for supplying a projection beam PB of EUV radiation;

a first object table (mask table) MT provided with a mask, or first object, holder for holding a mask MA (e.g. a reticle), and connected to first positioning means for accurately positioning the mask with respect to item PL;

a second object table (substrate or wafer table) WT provided with a substrate, or second object, holder for holding a substrate W (e.g. a resist-coated silicon wafer), and connected to second positioning means for accurately positioning the substrate with respect to item PL;

a projection system ("lens") PL (e.g. a mirror group) for imaging an irradiated portion of the mask MA onto an exposure area C of a substrate W held in the substrate table WT.

As here depicted, the apparatus is of a reflective type (i.e. has a reflective mask). However, in general, it may also be of a transmissive type, for example.

The radiation system may include a source LA (e.g. an Hg lamp, an excimer laser, an undulator or wiggler provided around the path of an electron beam in a storage ring or synchrotron or a plasma source) which produces a beam of UV or EUV radiation. This beam is caused to traverse various optical components comprised in the illumination system IL - e.g. beam shaping optics, an integrator and a condenser - also included in the radiation system so that the resultant beam PB has a desired shape and intensity distribution in its cross-section.

The beam PB subsequently intercepts the mask MA which is held on a mask table MT. Having traversed the mask MA, the beam PB traverses the lens PL, which focuses the beam PB onto an exposure area C of the substrate W. With the aid of the interferometric displacement measuring means IF, the substrate table WT can be moved accurately by the second positioning means, e.g. so as to position different exposure areas C in the path of the beam PB. Similarly, the first positioning means can be used to accurately position the mask MA with respect to the path of the beam PB. In general, movement of the object tables MT, WT will be realized with the aid of a long-stroke module (course positioning) and a short-stroke module (fine positioning), which are not explicitly depicted in Figure 1. In the case of a waferstepper (as opposed to a step-and-scan apparatus) the mask table may be connected only to a short-stroke positioning device, to make fine adjustments in reticle orientation and position.

The depicted apparatus can be used in two different modes:

1. In step-and-repeat (step) mode, the mask table MT is kept essentially stationary, and an entire mask image is projected in one go (i.e. a single "flash") onto an exposure area C. The substrate table WT is then shifted in the X and/or Y directions so that a different exposure area C can be irradiated by the beam PB;

2. In step-and-scan (scan) mode, essentially the same scenario applies, except that a given exposure area C is not exposed in a single "flash". Instead, the mask table MT is movable in a given reference direction (the so-called "scan direction", e.g. the Y direction) with a speed v, so that the projection beam PB is caused to scan over a mask image; concurrently, the substrate table WT is moved in the same or opposite direction at a speed

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V = Mv, in which M is the magnification of the lens PL (typically, M = 1/4 or 1/5). In this manner, a relatively large exposure area C can be exposed, without having to compromise on resolution.

In a specific embodiment of the present invention, an optical component is cleaned of contaminant particles by directing a beam of infra-red or microwave radiation at the optical component to be cleaned. For example, the optical component to be cleaned may be the mask. However, the present invention may be used to remove contaminants from any component in the system, for example the optical components contained within the illumination or projection systems. The present invention can be applied to one or several optical components either simultaneously or separately.

In this embodiment it will be assumed that the radiation system produces UV light with a wavelength of 157nm, although other wavelengths, such as 126nm, may also be used.

Figure 2 shows the mask stage of this embodiment of the invention in more detail. The mask M is irradiated with microwave and/or infra-red radiation. In the embodiment of the invention depicted in Figure 2 the radiation is infra-red radiation generated from infra-red source IRS. Any contaminant molecules which absorb the radiation will gain energy and may evaporate from the surface to which they are adsorbed. In this embodiment, the mask is irradiated *in situ*. Irradiation may take place prior to or simultaneously with exposure. It is also envisaged that the mask, or other optical component which requires cleaning, may be irradiated prior to insertion in the lithographic projection apparatus.

Suitable sources of infra-red radiation IRS included incandescent lamps. Suitable sources of microwave radiation include cavity resonators, backward wave oscillators and "Klystrons". The source may be a broad band emitter which provides radiation of a range of wavelengths, or may provide radiation of a single, or a narrower range of wavelengths. Preferably the source is adjustable so that it can be tuned to different wavelengths; filters may also be used to select desired wavelengths.

The bonds within any molecule rotate and vibrate at specific frequencies. Generally, rotational frequencies lie in the microwave region and vibrational frequencies in the infra-red region. Therefore, irradiating at one or a range of wavelengths in these regions causes excitation, via rotation or vibration, of the contaminant molecule leading to its removal. Suitable wavelengths or ranges of wavelengths for the microwave or infra-red radiation fall within the range 0.3 cm^{-1} to 4600cm^{-1}, typically from 1 to 100 cm^{-1} if rotational excitation is used (microwave region) or from 400 to 4600 cm^{-1} if vibrational excitation is used (infra-red region).

One embodiment of the present invention involves targetting one or more specific contaminant molecules by irradiating at a characteristic rotational or vibrational frequency of that molecule, or of a bond within that molecule. For example, when considering vibrational excitation, an alkyl C-H bond has a stretching frequency in the range 2800cm^{-1} to 3000cm^{-1} and an O-H bond has a stretching frequency in the range 2800cm^{-1} to 3800cm^{-1}. The precise frequency of each vibration in any given molecule will be determined by a number of factors such as steric influences and non-covalent bonding (e.g. hydrogen bonding). Approximate vibration frenquencies for a variety of chemical bonds are given in the table below:

Vibration	Frequency (cm^{-1})
O-H	2800-3800
O-H (Si-OH)	3800
O-H (Si-OH)	4600
C-H	2960
C-C	900
C=C	1650
C=O	1700
S=O	1310
C-F	650
Si-Si	430

Infra-red radiation of one of the above specific frequencies or a range of frequencies including one of the above frequencies can therefore be used to excite a molecule containing the corresponding type of bond.

Many of the contaminant molecules present in a lithographic apparatus contain O-H bonds, for example water and alcohols, and therefore a suitable range of frequencies is from $2800cm^{-1}$ to $3700cm^{-1}$. The vibration frequency of water is at the upper end of this range, so if it is desired to specifically target water molecules, a frequency of $3500cm^{-1}$ to $3700cm^{-1}$ can be used. Similarly, other contaminants can be targeted by irradiating the optical component with radiation having a frequency which corresponds to a vibration frequency of the relevant contaminant. Several frequencies may be irradiated in turn or simultaneously such that several different contaminants are targeted.

Whilst it may be desirable to use a certain wavelength to remove a particular type of contaminant, it may alternatively be required that a broad range of wavelengths be used, for example by using a broad-band emitter as the source of microwave and/or infra-red radiation. This will energize, and cause evaporation of, a wide variety of different molecules at once.

If desired, the absorption of the microwave and/or infra-red radiation can be monitored using sensor 2. This is described further in embodiment 2.

It is envisaged that the cleaning method of the present invention may be used in combination with other cleaning methods, for example methods involving the use of ozone and/or UV radiation.

Embodiment 2

In a second embodiment of the invention, which is the same as the first embodiment, except as described below, the apparatus is fitted with a sensor 2 to monitor the absorption of the infra-red radiation by the contaminants on the surface of the optical components. As for embodiment 1, infra-red radiation has here been utilised, but it is also envisaged that microwave radiation may be used. In Figure 2, sensor 2 is depicted as

monitoring the absorption of infra-red radiation directed at the mask, but it may also be used to monitor absorption of radiation directed at any optical component.

As is depicted in Figure 2, the optical component may be reflective, and the sensor will therefore measure the reflectance of the infra-red radiation. However, if the mask is of a transmissive type, the sensor will be positioned such that it measures the degree of transmission through the mask or other optical component.

The degree of absorption of the infra-red radiation indicates the degree of coverage of the optical component with contaminants. Thus, the sensor may be used to indicate whether the optical component in question is sufficiently clean for exposure to take place, or whether further cleaning is required. Regular use of this detection process may be desirable so that it can be determined when an optical component requires cleaning.

The sensor may also be used during the cleaning process. Cleaning is carried out as described in Embodiment 1, and whilst irradiation is taking place, the absorption of said radiation is monitored using sensor 2. When the sensor indicates that the absorption level has dropped below a sufficient level, and thus the contamination level of the optical component is acceptable, the cleaning process may be stopped and exposure carried out.

Further, if the sensor indicates that the optical component has not been sufficiently cleaned by the infra-red method of the present invention, other techniques may be employed.

Embodiment 3

In a third embodiment of the invention, which is the same as the first embodiment except as described below, the partial pressure of water in the system is reduced by irradiating with infra-red or microwave radiation, preferably infra-red radiation.

In this embodiment, the radiation system produces radiation in the extreme ultraviolet (EUV) range. For example, the radiation may have a wavelength below about 50 nm, preferably below about 20nm and most preferably below about 15nm. An example of a wavelength in the EUV region which is gaining considerable interest in the

lithography industry is 13.4 nm, though there are also other promising wavelengths in this region, such as 11 nm, for example.

In this embodiment the interior of the lithographic apparatus is irradiated with IR light from IR source IRS. The frequency of the radiation is a frequency which is absorbed by water molecules. For example a frequency or a range of frequencies within the range of from 3500cm^{-1} to 3700cm^{-1}, preferably about 3400cm^{-1} (2.94μm). It is preferred that the radiation is a single frequency or a narrow range of frequencies.

Irradiation may be dynamically controlled with a very short response period. Sensor 2, which may in this embodiment be a mass spectrometer which can measure the partial pressure of water in the apparatus, may be used to dynamically control the irradiation. Thus, a pulse of irradiation may applied to the system when the sensor indicates that the partial pressure of water has risen above a particular level.

Irradiation in this manner causes evaporation and removal of water molecules and thus decreases the partial pressure of water in the system. This leads to a reduction in oxidation of any mirrors present in the apparatus. Exposure may be carried out at any time after IR irradiation, including immediately afterwards, since the apparatus itself is not heated during IR irradiation and there is therefore no need for a cooling period. IR irradiation may alternatively be carried out simultaneously with exposure.

Although this text has concentrated on lithographic apparatus and methods whereby a mask is used to pattern the radiation beam entering the projection system, it should be noted that the invention presented here should be seen in the broader context of lithographic apparatus and methods employing generic "patterning means" to pattern the said radiation beam. The term "patterning means" as here employed refers broadly to means that can be used to endow an incoming radiation beam with a patterned cross-section, corresponding to a pattern that is to be created in a target portion of the substrate; the term "light valve" has also been used in this context. Generally, the said pattern will correspond to a particular functional layer in a device being created in the target portion,

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such as an integrated circuit or other device. Besides a mask on a mask table, such patterning means include the following exemplary embodiments:

A programmable mirror array. An example of such a device is a matrix-addressable surface having a viscoelastic control layer and a reflective surface. The basic principle behind such an apparatus is that (for example) addressed areas of the reflective surface reflect incident light as diffracted light, whereas unaddressed areas reflect incident light as undiffracted light. Using an appropriate filter, the said undiffracted light can be filtered out of the reflected beam, leaving only the diffracted light behind; in this manner, the beam becomes patterned according to the addressing pattern of the matrix-adressable surface. The required matrix addressing can be performed using suitable electronic means. More information on such mirror arrays can be gleaned, for example, from United States Patents US 5,296,891 and US 5,523,193, which are incorporated herein by reference.

A programmable LCD array. An example of such a construction is given in United States Patent US 5,229,872, which is incorporated herein by reference.

Whilst we have described above specific embodiments of the invention it will be appreciated that the invention may be practiced otherwise than described. The description is not intended to limit the invention.

CLAIMS:

1. A lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table for holding a mask;

a second object table for holding a substrate; and

a projection system for imaging an irradiated portion of said mask onto a target portion of said substrate; characterized by:

a source for supplying microwave and/or infra-red radiation.

2. Apparatus according to claim 1, wherein said radiation of said projection beam has a wavelength of less than 180nm, preferably 157nm or 126nm.

3. Apparatus according to claim 1, wherein said radiation of said projection beam has a wavelength of less than 50nm, preferably about 13.4nm or 11nm.

4. Apparatus according to any one of claims 1 to 3, wherein said microwave and/or infra-red radiation is infra-red radiation having a wavelength or a range of wavelengths in the range of from 400 cm^{-1} to 4600 cm^{-1}.

5. Apparatus according to claim 4, wherein said infra-red radiation has a wavelength or a range of wavelengths in the range of from 3500 cm^{-1} to 3700 cm^{-1}, preferably about 3400 cm^{-1}.

6. Apparatus according to any one of claims 1 to 3, wherein said microwave and/or infra-red radiation is microwave radiation having a wavelength or a range of wavelengths in the range of from 1 to 100 cm^{-1}.

7. Apparatus according to any one of the preceding claims, wherein said microwave and/or infra-red radiation is directed at an optical component in the lithographic apparatus, preferably the mask.

8. A method of manufacturing a device using a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table for holding a mask;

a second object table for holding a substrate; and

a projection system for imaging irradiated portions of said mask onto target portions of said substrate; the method comprising the steps of:

providing a mask bearing a pattern to said first object table;

providing a substrate provided with a radiation-sensitive layer to said second object table;

irradiating portions of the mask with said projection beam; and

imaging said irradiated portions of the mask onto said target portions of said substrate; characterized by the step of:

removing contaminant particles from the apparatus by irradiating with microwave and/or infra-red radiation.

9. A method according to claim 8, wherein said irradiation with microwave and/or infra-red radiation is carried out before exposure to the projection beam.

10. A method according to claim 8, wherein said irradiation with microwave and/or infra-red radiation is carried out simultaneously with exposure to the projection beam.

11. A method according to any one of claims 8 to 10, wherein said contaminant particles are water.

12. A method of manufacturing a device using a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table for holding a mask;

a second object table for holding a substrate; and

a projection system for imaging irradiated portions of said mask onto target portions of said substrate; the method comprising the steps of:

providing a mask bearing a pattern to said first object table;

providing a substrate provided with a radiation-sensitive layer to said second object table;

irradiating portions of the mask with said projection beam; and

imaging said irradiated portions of the mask onto said target portions of said substrate; characterized by the step of:

determining the level of contamination of an optical component by irradiating said optical component with microwave and/or infra-red radiation and monitoring the degree of absorption of said radiation.

13. A device manufactured according to the method of any one of claims 8 to 12.

ABSTRACT

CLEANING OF OPTICAL ELEMENTS IN LITHOGRAPHIC PROJECTION APPARATUS

Pre-cleaning or *in situ* cleaning of optical components for use in a lithographic projection apparatus can be carried out by irradiating the optical component with microwave and/or infra-red radiation, preferably infra-red radiation having a wavelength or a range of wavelengths in the range of from 400cm^{-1} to 4600cm^{-1}. This technique is particularly suitable for cleaning a mask. By monitoring the absorption of microwave and/or infra-red radiation directed at a contaminated optical component, the degree of contamination of said component can be qualified. This method is also suitable for reducing the partial pressure of water in EUV apparatus.

Fig. 2

Fig. 1

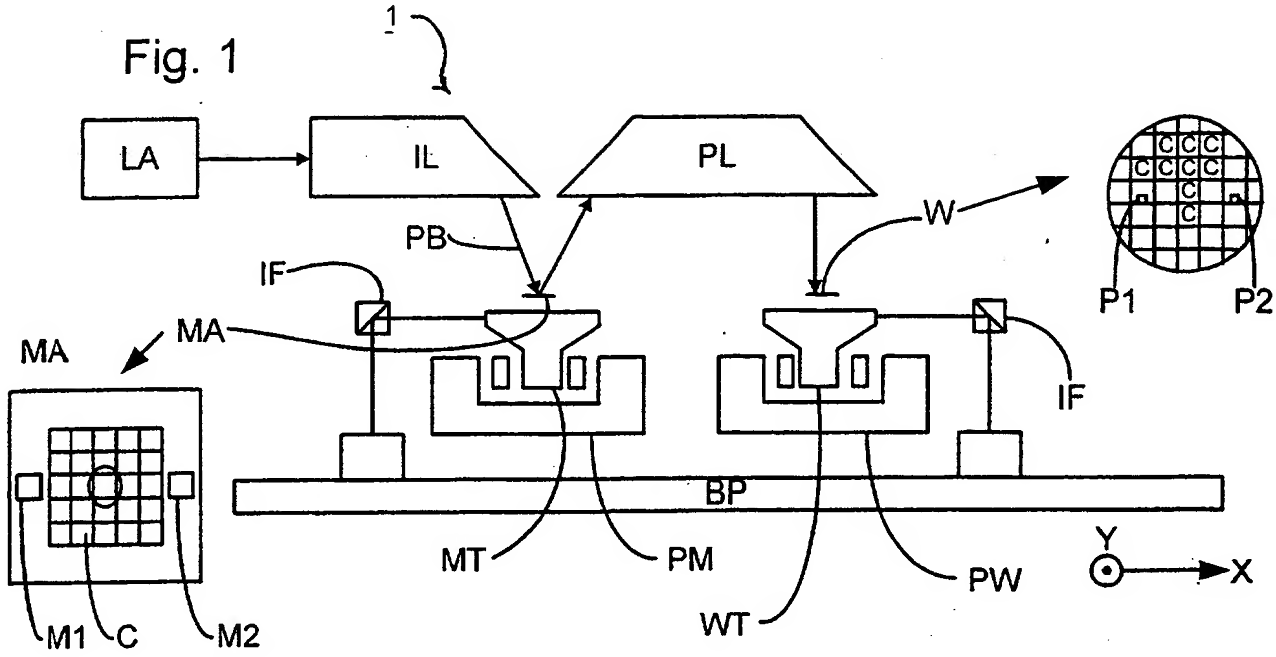

Fig. 2